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The soundscapes of Baja California Sur: Preliminary results from the Cañón de Santa Teresa rock art landscape

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ABSTRACT

This article argues that the recent emphasis on quantitative methods should also include the application of rigorous science-based methodologies for the study of sound and acoustics among past communities. The benefits of including methods developed in acoustical physics have been shown with the analysis of the rock art landscape in the Cañón de Santa Teresa gorge in Baja California Sur (Mexico), where the Great Mural rock art tradition was produced. Thanks to a thorough examination of a series of monaural and binaural acoustic parameters, we have been able to conclude that the artists selected the best sonic landscapes in which to create their rock art, both paintings and carvings, especially the latter. We have also been able to demonstrate that the sector of the canyon with a special concentration of two profusely painted caves, Cueva Pintada and Las Flechas, is precisely that with the most favorable acoustic conditions in the whole tested area.

1. Introduction

Archaeologist Kristian Kristiansen has recently suggested that archaeology is going through a Third Science Revolution (Kristiansen, 2014). In his widely-read article he proposes that the post-processual theoretical framework dominant from the mid-1980s has experienced an increasing fragmentation into a multitude of approaches, some of them, as he puts it, esoteric. This contrasts with a definitive return of quantitative methods and science-based knowledge, in what he defines as a revised form of the processual approach. He argues that this change is happening thanks to the new possibilities opened up by applying quantitative and modeling methods, by processing large databases in areas such as genomics and strontium isotope analysis, and the theoretical power behind new knowledge. Archaeology, he claims, has a need for “theorizing that is more integrated in actual modeling” (Kristiansen, 2014: 25). Although in his article Kristiansen explicitly mentions the study of materiality as one of the new concerns in many human sciences, we would like to argue here that the study of the immaterial, intanglible aspects of culture is also benefitting from the novel opportunities brought about by the application of newly developed scientific methods. In this respect, we share his dream, which is to be able to release the sounds of prehistory. As this article will show, in the last decade the study of past cultural soundscapes has been enhanced by the use of increasingly accurate procedures, allowing archaeologists to approach those sonic landscapes in innovative ways. We will reveal the potential of scientific-based methods in the study of the rock art landscape of the Cañón de Santa Teresa/Arroyo de San Pablo (Baja California Sur, Mexico).

A seminal event in the application of science-based methods for the study of sound in the past was the conference on “Acoustics, Space and Intentionality. Identifying intentionality in the ancient use of acoustic space and structure” held in the McDonald Institute for Archaeological Research in Cambridge on 27–29 June 2003. Published under the title of *Archaeoacoustics* (Scarre and Lawson, 2006), the articles dealt, on the one hand, with archaeological sites and monuments as diverse as megaliths, Roman theatres, open-air rock art sites, Paleolithic caves and medieval buildings. On the other hand, a few authors focused on musical instruments, such as flutes, lyres and lurs. Interestingly, the

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Fig. 1. Map of Baja California with the Central Sierras indicated (based on Laylander, 2015, Fig. 1).

methodology used – or proposed – for studying the intentionality of sound in the past came from disciplines as varied as physical acoustics, neuroacoustics and musicology. This book could be seen as the way archaeology has participated in a new interest in sound appearing in many different sciences (Feld and Brenneis, 2004, p 461). Of interest here is the article about rock art and acoustics research written by Steve Waller, which demonstrated the potential of applying scientific methods to the verification of intentionality in the location of rock art. Waller, (2006) explored the strength of echoes measured in dB at the rock art landscape of Horseshoe Canyon (Utah) and demonstrated the direct relationship between sounds with high values and the presence of rock art. At the time of this publication he had already published several other acoustic tests in rock art landscapes in the US (Waller, 2000, 2002). Other authors had also proposed simple but effective methods to quantitatively determine sonic properties. This was the case of Joakim Goldhahn's measurement of the sound pressure level (SPL) in the area of Namforsen (Sweden) (Goldhahn, 2002). The results obtained demonstrated the intentional placement of rock art in proximity to loud roaring rapids and waterfalls. Thus, the selection of suitable surfaces to engrave was not due to availability, but to a deliberate decision to select rocks associated to loud ambient sounds. Other more intuitive methods were also proposed by the pioneer Iégor Reznikoff (Reznikoff, 1987, 1995, 2018).

In the last few years, the field of acoustics in rock art landscapes has shown an increasing sophistication in quantitative methods, as expected following Kristiansen's observations (Kristiansen, 2014). In Finland, for example, the intuitive methods used by the pioneer Igéor Reznikoff (1995) have recently been substituted by Riitta Rainio's precise controlled audio recordings (Rainio et al., 2014, 2017). A different research team has also gone beyond Reznikoff's analysis of Upper

Fig. 2. Cueva Pintada. Photograph by M. Díaz-Andreu.

Fig. 3. Piedra de Chuy and custodian Santos. Photograph by M. Díaz-Andreu.

Palaeolithic painted caves (Reznikoff, 1987, 1995) and developed a more detailed analysis, integrating methods from acoustical physics (Till, 2014; Fazenda et al., 2017). The work undertaken by our archaeoacoustics team at the University of Barcelona serves as a good example of the evolution towards a greater involvement of science-based methods in rock art studies. Our earliest attempts at measuring echoes and reverberation (Díaz-Andreu and García Benito, 2012) have increased in complexity thanks to cooperation with acoustic engineers and the adoption of their methods (Díaz-Andreu et al., 2017; Mattioli and Díaz-Andreu, 2017; Mattioli et al., 2017). At the same time, however, we still firmly believe that, wherever possible, it is essential to combine the search for information through scientific methods with other types of data, such as that obtained from ethnographic and ethnohistorical sources (see, for example Rainio et al., 2017). This is precisely our aim in this article. In the following pages we will undertake the study of the rock art soundscapes of the Sierra de San Francisco in Baja California, making use of new scientific methodologies inspired from acoustical physics. Before doing so, however, we will review the information from ethnohistorical sources, searching for aspects that may be helpful both to formulate the acoustic tests and to understand their results. This is the first time that this perspective has been applied to the study of Latin American rock art soundscapes.

2. The case study area in context

2.1. The Great Mural rock art tradition

The case study area is the Arroyo de San Pablo canyon, a main artery running for about 43 km from southeast to northwest through the Sierra de San Francisco in Baja California Sur. We will mainly focus on a segment of the Arroyo de San Pablo between Rancho Santa Teresa and Boca de San Julio that receives the name of Cañón de Santa Teresa (Santa Teresa canyon). As our tests have mainly focused on this sector of the canyon, and this is the most frequently used toponym in the bibliography, in this article we will mainly allude to Cañón de Santa Teresa. The Sierra de San Francisco is one of the many mountain ranges running parallel to the Gulf of California and the Pacific coasts throughout the Baja California peninsula. The Arroyo de San Pablo is located in the geographical center of the peninsula, in the Central Sierras region, where the distance from coast to coast is at its widest (Fig. 1). With a desert climate the area receives about 100 mm a year of rain. Although water is scarce, there are some springs and reservoirs, the latter being known locally as *tinajas* (Gutiérrez Martínez, 2017, pp 7–10).

The rock art found in the Cañón de Santa Teresa, in the municipality of Mulegé, forms part of the larger area of the outstanding Great Murals. The Great Mural rock art tradition is characterized by its impressive larger-than-life figures of people and animals (Fig. 2). The style is mainly naturalistic, although there are also some abstract motifs. Human motifs represent mainly adult men, although there are also women and some infants. More than 30 species of terrestrial and aquatic animals are depicted in the rock art. They include eagles, rabbits, whales, and fish, although the most frequently depicted and appear closely associated with human motifs are deer, bighorn sheep (*borrego cimarrón*) and sand pronghorn (*berrendo*). There are also a few reptiles, including turtles. The figures are mainly painted in red and black, and to a lesser extent white and yellow. The number of motifs at each site varies from one or two to hundreds. There are also carvings with vulva-like forms and abstract designs, both in sites with only carvings or in others associated with paintings (Fig. 3) (Hambleton, 1979; Crosby, 1997; Gutiérrez Martínez and Hyland, 2002; Viñas, 2013). The Great Mural rock art tradition is found in the Central Sierras area, covering an area of about 250 km by 70 km, from the Sierra de San Borja and Sierra de San Juan to the north, to the Sierra de Guadalupe towards the south, leaving in the very center the Sierra de San Francisco (Fig. 1). Of the four different sierras, the purest Great Mural style is found in the Sierra de San Francisco itself, while the style is 'diluted' as it moves north or south (Gutiérrez Martínez, 2017, p. 9). The Sierra de San Francisco is now a protected area and was inscribed in the World Heritage List in 1993 (whc.unesco.org/en/list/714) (Gutiérrez Martínez and Hyland, 2002, pp. 379–400).

The first scientific publication on the Great Mural rock art was written by Léon Diguet, a French industrial chemist working at the El Boleo copper mine. He identified some general characteristics of the paintings and described four sites he had visited of the thirty then known to him (Diguet, 1895). After several decades of little activity, the archaeologist Clement W. Meighan surveyed the Cueva Pintada in the 1960s (Meighan, 1966), and he was followed by Harry Crosby, a San Diego writer and photographer (Crosby, 1975). Those who came after are described in the many good summaries of the complex history of research into this tradition (Ritter, 1991, Gutiérrez Martínez, 2013, pp. 14–16, Viñas, 2013, pp. 15–18, Rubio, 2014, pp. 25–46). However, as can be seen, most of the research has taken place in the last three decades. This includes some excavations at sites such as Cueva Pintada and Cueva de la Soledad, with finds including a lithic industry manufacturing flakes and querns (*metates*), as well as ropes and faunal remains. The dates are mainly from the last few centuries, although there is one date from the fifth millennium found at Cueva de la Soledad (Gutiérrez Martínez and Hyland, 2002, pp. 195–251).

The dating of the Great Mural rock art tradition has been a matter of debate. Initially, the excellent conservation of rock art paintings,

Table 1
Radiocarbon dates of painting material of Great Mural depictions. Radiocarbon dates have been calibrated using the internationally agreed atmospheric curve IntCal13 (Reimer et al., 2013), and the OxCal v4.3 computer program (Bronk Ramsey, 2001, 2009). Calibrated ranges have been obtained using the probability method (Stuiver and Reimer, 1993) and the endpoints were rounded out by 10 year when the error was greater than or equal to 25 year and by 5 year when the error was less than 25 year (Stuiver and Polach, 1977; Millard, 2014).

Site	Figure	Laboratory	Lab. Code	Date BP	Calibrated date (68% confidence) Cal BC/AD	Calibrated date (95% confidence) Cal BC/AD	References
San Borjita	Human figure (black and red colour)	Rafter Radiocarbon Lab.	–	7500	–	–	Gutiérrez Martínez et al. (2003):4
San Borjita	Human figure (black colour)	Rafter Radiocarbon Lab.	San Borjitas 11	5525 ± 75	4460-4280 cal BC	4530-4240 cal BC	Watchman et al. (2002):948
San Borjita	Human figure (black colour)	Rafter Radiocarbon Lab.	San Borjitas 3	5325 ± 95	4310-4050 cal BC	4340-3970 cal BC	Watchman et al. (2002):948
Cueva del Ratón	Human figure (red colour)	University of Arizona	AA-8221	5290 ± 80	4230-4010 cal BC	4330-3970 cal BC	Fullola et al., (1993):9; Rubio (2014):82
La Trinidad	Deer figure (red colour)	Rafter Radiocarbon Lab.	La Trinidad 5	5225 ± 85	4230-3960 cal BC	4320-3800 cal BC	Watchman et al. (2002):948
San Borjita	Human figure (red colour)	Rafter Radiocarbon Lab.	San Borjitas 5	5025 ± 75	3940-3710 cal BC	3960-3660 cal BC	Watchman et al. (2002):948
Cueva del Ratón	Cougar figure (black colour)	University of Arizona	AA-8220	4845 ± 60	3700-3530 cal BC	3770-3390 cal BC	Fullola et al., (1993):9; Rubio (2014):82
El Pilo	Deer figure (white colour)	Rafter Radiocarbon Lab.	El Pilo 3	4790 ± 70	3650-3390 cal BC	3700-3380 cal BC	Watchman et al. (2002):948
La Palma	Ten black flakes of paint	University of Arizona	AA25167	3245 ± 65	1610-1450 cal BC	1690-1410 cal BC	Gutiérrez Martínez and Hyland (2002):94
San Gregorio II	Black paint overlying a rock substrate	University of Arizona	AA25166	2985 ± 65	1370-1110 cal BC	1400-1030 cal BC	Gutiérrez Martínez and Hyland (2002):94
Cueva del Ratón	Human figure (red colour)	Texas A&M University	4C36	1325 ± 360	270–1120 cal AD	110–1390 cal AD	Fullola et al., (1993):9; Rubio (2014): 82
Cueva del Ratón	Deer figure (black colour)	Texas A&M University	4C35	295 ± 115	1450-1950 Cal AD	1428-1950 Cal AD	Fullola et al., (1993):12; Rubio (2014):82

together with the recent chronology of some artifacts associated with them within the archaeological record excavated in the shelters, made experts suspect of their antiquity (Meighan, 1966, pp. 379). However, old dates obtained from painting material so far sampled from the Great Mural rock art tradition provided an unsuspected wide chronological range (Table 1). The earliest date for its production points to the mid-5th millennium cal BC. Six dates are between the second half of the 5th millennium cal BC and the first half of the 4th millennium cal BC. After a gap in the dates during the 2nd millennium, there are two samples dated to the 2nd millennium cal BC, one in the first millennium AD and a last one that seems to be dated in the colonial era (see Table 1). This radiocarbon dataset means that this rock art tradition was also in use for more than six millennia and the proposed chronology predates the Comundú culture, the archaeological culture that is linked to the Cochimí, whose beginnings are temporarily located by scholars in the first centuries of our era (Ritter, 2006; Ritter and Aceves Calderón, 2006). However, this would not be the case of a few motifs related to the Comondú-Cochimí tradition that Viñas identified in his study of the Cueva Pintada. For him Phase Six or E is represented by the schematic-abstract motifs made up of smaller figures painted with a less refined technique. The latest phase, the seventh or Phase F, is identified with the Historical Yumana-Cochimí tradition (Viñas, 2013, pp. 130, 207–208, Figures 62, 124).

2.2. *The ethnohistorical sources*

The territory of Baja California was first visited by Europeans in 1533, but only in the 18th century it was effectively colonized. It has been calculated that between the first arrival and 1697, the Spaniards occupied the land for a total of five years, and even then only partially (Mathes, 2006: 42). The Jesuit Order received official permission to evangelize California in 1697 and the first mission after this was established in Nuestra Señora de Loreto, about two hundred kilometers to the Las Palmas culture south of our study area (Ortega Noriega, 2010: 153). Between 1697 and 1768, the year of their expulsion, the Jesuits founded a total of eighteen missions, several of them around the area where the Great Mural tradition is located (Massey, 1949; Rubio, 1991, pp. 52–53). From this period we have written accounts by the Jesuits Miguel del Barco (1706–1790), who lived among the Cochimí at the San Javier mission from 1739 to 1767, and Juan Jacobo Baegert (1717–1772), a father minister among the Guaycura at the San Luis Gonzaga mission from 1750 to 1767. In addition, there are Jesuits who wrote about the natives of Baja California, even though those missionaries had never set foot in the area. They did so by gathering the information compiled by others; examples of this are the books by Francisco Xavier Clavijero (1731–1787) and Miguel Venegas (1680–1764) (Rubio, 1991; Mathes, 2006).

When the first Spaniards arrived in Baja California Sur, the Arroyo de San Pablo area in the Sierra de San Francisco, our study zone, was populated by the Cochimí. According to Miguel del Barco, this ethnic group did not consider the Great Murals as their own doing. The local population saw them as a proof of a previous presence of giants in the area. Del Barco transcribed the description of one of these caves – probably El Palmarito (Viñas, 2013: 56) – written by Father José Mariano Rothea of the San Ignacio mission, most likely at the latter's request (Barco 1773-1780 (1973), pp. 211–212). Having received the same request, Father Francisco Escalante of the Santa Rosalía mission visited another site (Barco 1773-1780 (1973), p. 212), possibly the Cueva de San Borjita in the Sierra de Guadalupe (Viñas, 2013, p. 56).

Who then were the authors of the Great Mural tradition? When asked by the Jesuits about their origins, the Cochimí consistently stated that they originated from the north (Rubio, 1991, p. 61). In the 1940s, the anthropologist William Clifford Massey (1917–1974) wrote a pivotal study on the "Tribes and Languages of Baja California" (Massey, 1949, p. 302). He mentioned that to the north there were other groups who spoke languages related to that of the Cochimí reaching as far as Upper California and Arizona. Nowadays, however the Cochimí and Yuman languages are considered to be too divergent to be closely connected, although it is thought that they may both derive from a common, distant root (Mixco, 2006, p. 28). Massey also proposed that the geographical extension of the original population to inhabit the whole of Baja California, which he identified with the makers of Las Palmas culture, had gradually been limited to the southern part of the peninsula. Because of migrations coming from the north, Las Palmas culture had been replaced in the north and central regions of the peninsula by the Comondú culture. In turn, the Comondú culture had been substituted by the last migration into the Peninsula, the California Yuman culture (Massey, 1966). If Massey was right, however, the date of these two migrations is uncertain, although we can only speculate that the first migration, the one in which the Comondú culture arrived in the area, could be dated to the end of the archaic period (cf. Laylander, 2018, Fig. 8). Along those lines of thought, the Great Mural tradition would have been produced by those peoples who, according to Massey's theories, were later pushed southwards and whose descendants were described by the missionaries as Guaycura and Pericú. The distribution of rock art styles in Baja California Sur shows another area of representational art in the territory inhabited by the Pericú when the Europeans arrived, but that looks very different. However, it is important to realize that Massey's theories were propounded at a time when migrations were the main reason to explain culture change and some serious challenges have been raised against his theories (Gutiérrez Martínez and Hyland, 2002, pp. 66–71). We need more data before either theory can be proved or disproved.

The increasing consensus that the Great Mural tradition dated from much earlier than those Cochimí populations the European settlers encountered in the 18th century means that the information in the literature produced at the time should be treated with care when inferring anything related to those who created and used the rock art. This does not mean that rock art specialists should ignore the sources. In 1959 Aschmann was already arguing that even if the historical peoples of the Central Desert had not been the lineal descendants of the previous inhabitants of the territory in a biological or linguistic sense, they probably were the cultural heirs of much of the human experience on their lands (Aschmann, 1959, p. 51 in Viñas, 2013, pp. 221–222). We do not have enough data to ascertain who was in the area, but the important point for us is that the sources point that all the groups that inhabited the Baja California peninsula shared some similarities, including painting their whole bodies with the colors we see in the paintings and the importance of dancing (see below).

2.3. Information about sound in the ethnohistorical sources

What information do we have in the ethnohistorical sources on anything related to sound? There is plenty of literature on Northern Baja California, but this is not the place to review that in full. Dominican Luis Sales reported about that the northern Yuman ceremonies were held in *barrancos* (dry river beds) at night. Painted wooden boards (*tablas*) representing venerable ancestors were used by the shaman as mnemonic devices. Sales alluded to the shaman as *el viejo*, the old man, although he explained that in the local languages they were called *quama* or *cusiyae* (Sales 1794, p. 59). These ceremonies included singing and rattles (*sonajas*) and sometimes drums (*tamboril a modo de zambomba*) and another percussion instrument with small bones (Sales 1794, pp. 67–73). After the death of man or a woman, the shaman also called in the community and used a flute (*pito* or *pífano*) to call the attention of the community in key moments of the ceremony (Sales 1794, pp. 75–80). In addition to rattles and flutes, the Yumans also used bullroarers (Wilken-Robertson and Laylander, 2006, p. 79). In 1893, the Paipai ethnic group to the north of Baja California were still using bullroarers in mourning ceremonies to frighten away ghosts (Laylander, 2005, p. 172). Similar ceremonies to those described for the Yumans are also mentioned in the historical sources written about the area of Baja California Sur, although these are not as eloquent regarding the use of musical instruments.

The importance of dances can also be read in Baegert's description of the Guaycura, where he stated that "the dance, which always accompanies their singing, is … a … kind of gesticulating, jumping, and hopping, of walking in a circle, and of … advances and retreats… They enjoy this so greatly that they spend half or even whole nights with such singing and dancing" (Baegert 1772 (1952), p. 89). He explained that there was a variety of sorcerers and conjurers, some of which "at times go into a cave and by changing their voices try to give the impression to the people that they are conversing with some mysterious being" (Baegert 1772 (1952), p. 90). He continued "when these charlatans and windbags appeared in their gala ceremonial apparel they were enveloped in long capes or mantles made entirely of human hair" (ibidem). The use of the voice described by Baegert was also mentioned by Clavijero, who explained that in their dances the Indians – although no specific group is mentioned – imitated the movements and voices of the animals (Clavijero 1789 (1982)).

Even though in the southern half of the peninsula of Baja California the sources are silent about the use of musical instruments, those mentioned above have been found in excavations or have somehow arrived in museums. Thus, in 1961, Massey published his study of an excavation undertaken in Bahía de los Angeles. The small natural cave was excavated by the naturalist Edward Palmer in 1887 and two flutes and a bullroarer were found associated with a collective burial of seven individuals, one of them most likely a shaman (Massey and Osborne, 1961, p. 344, plate 15). In the Regional Museum of Anthropology and History of La Paz there is also a bullroarer found in the Sierra de la Giganta (Loreto) and a shell trumpet from the site of El Médano, Cabo San Lucas (Los Cabos) (Harumi Fujita, pers. comm. 2 April 2019).

In sum, the sources tell us that in the Baja California peninsula communal ceremonies were held in *barrancos*, usually took place at night and could last for several days. In them there was dancing and singing and in some occasions they included the imitation of animals' sounds and movements. The ceremonies were accompanied by a series of musical instruments that included rattles, drums and flutes, instruments that have been archaeologically attested throughout the Baja California peninsula. Another musical instrument used in a different type of ceremony, such as mourning ceremonies, was the bullroarer. In one case it is mentioned that there was a particular ceremony in which a sorcerer manipulated his voice to talk to a "mysterious being" in a cave. Some of the material culture alluded to in the sources in association to ceremonies include the existence of painted wooden boards (*tablas*) that represented venerable ancestors and used by the shaman, and the shamans' use of a long cape of human hair. The archaeological record indicates the existence of both *tablas* and human-hair capes throughout the peninsula.

3. Acoustic tests

The University of Barcelona archaeoacoustics research group has been working on the acoustic analysis of rock art landscapes for almost a decade. In contrast with our previous work on the prehistoric rock art landscapes of the Central and Western Mediterranean, for which no ethnohistorical sources exist, the case of Baja California represented for us the challenge of taking into account the writings produced by the first European missionaries in the area. Having analyzed the sources, we had to decide whether to change our procedures in the light of the information obtained from them regarding sound and music. We decided against changing the procedures in the fieldwork phase of the project. This was because of the lack of direct information in the written sources on the acoustics of the landscape. According to research among hunter-gatherers (Ingold, 2000; Morley, 2006), we can confidently argue that this silence is in fact is a reflection of 18th-century European missionaries' lack of sensitivity to soundscapes, beyond that to the sound of church bells (Corbin, 1998; Mlekuz, 2004). The indirect information provided by the sources detailed in Section 2.3, however, had an effect in the post-processing phase of our analysis, as it led us to analyze a new set of monaural and binaural parameters (see below). This allowed us to obtain more sophisticated results regarding some of the activities mentioned in the sources: the use of space for music-making and singing.

The acoustic survey in the Cañón de Santa Teresa was undertaken between 27 March and 4 April 2018. It was aimed at investigating the

Fig. 4. Snapshot of the acoustic tests at CST-7, Cañón de Santa Teresa.

relationship between the acoustics of the landscape and rock art sites in the Cañón de Santa Teresa. The hypothesis to test was that landscapes and places with special acoustic parameters (perceived loudness, reverberation, speech and music clarity, listener envelopment, and apparent source width) had been behind the decision of both the selection of particular sectors of the canyon in which to paint and of rock shelters to be decorated with paintings and/or carvings. Accordingly, the fieldwork had two objectives. Firstly, to explore the relationship between the placement of rock art and the acoustics of the canyon; and, secondly, to examine the possible relationship between the placement of rock art and the acoustics of rock shelters.

3.1. Methodology

The Impulse Response (IR) methodology was the basis of our acoustic fieldwork tests. This measuring technique consists of capturing the acoustic 'signature' of an environment by analyzing how sound propagates from an emission point (sound source) to a receiver point (listener) (Farina et al., 2007; Kuttruf, 2009, pp. 255–261). In rock art landscapes, sound propagation is affected by complex reflections, diffractions and absorptions, mainly caused by hard surfaces (rock walls, cliffs, canyon slopes, etc.). As a consequence, the sound recorded at the receiver point may vary considerably from the original in terms of frequency, duration and spatial distribution. In some cases, particular landscape features can even add outstanding acoustic effects, such as long reverberation tails, distinct sound reflections (single echo, multiple echo, flutter echo), sound reinforcement (strength), variations in speech and music perception, and changes in the impression of being enveloped by sound.

In our IR tests we used large balloons as a sound source. These are very convenient for archaeological fieldwork in rough landscapes as they have the advantage of being extremely easy to carry and do not require electrical power. The balloons were blown up to a diameter of 40 cm, a size that allows both a massive explosion and sound propagation with good omnidirectionality, repeatability and a reasonably flat frequency spectrum (Pätynen et al. 2011). Air balloons were burst at a height of about 1.7m by sticking a pin into their lower part in order to avoid possible acoustical obstruction in the measurement field. Three air balloons were burst (Fig. 4) for each test point in order to create a consistent dataset for the post-processing phase. As a sound receiver we used an array of two microphones, each connected to a digital receiver to detect both monaural and binaural acoustic cues. The microphone array consisted of an omnidirectional condenser microphone (M231 Model by BSWA) connected to a Zoom H4N Digital Recorder. With it we were able to measure strength (G), reverberation (T20), speech clarity (C50) and music clarity (C80). We also used a first-order Ambisonics microphone (Brahma™ model) connected to a modified Zoom H2 Digital Recorder. The recordings made with the latter allowed us to measure listener envelopment (Lj) and apparent source width (Jlf). Both microphones were attached to a tripod. Before every recording session, the M231 condenser microphone was calibrated for 94 dB SPL at 1 kHz using a SC-05-type sound calibrator by Reed Instruments (Fig. 5).

In our previous study we published information on Transmission Loss (TL) (Mattioli and Díaz-Andreu, 2017) and the Direction of Arrival (DOA) of sound reflections (Mattioli et al. 2017). In our tests at the Cañón de Santa Teresa the mention in the ethnohistorical sources of

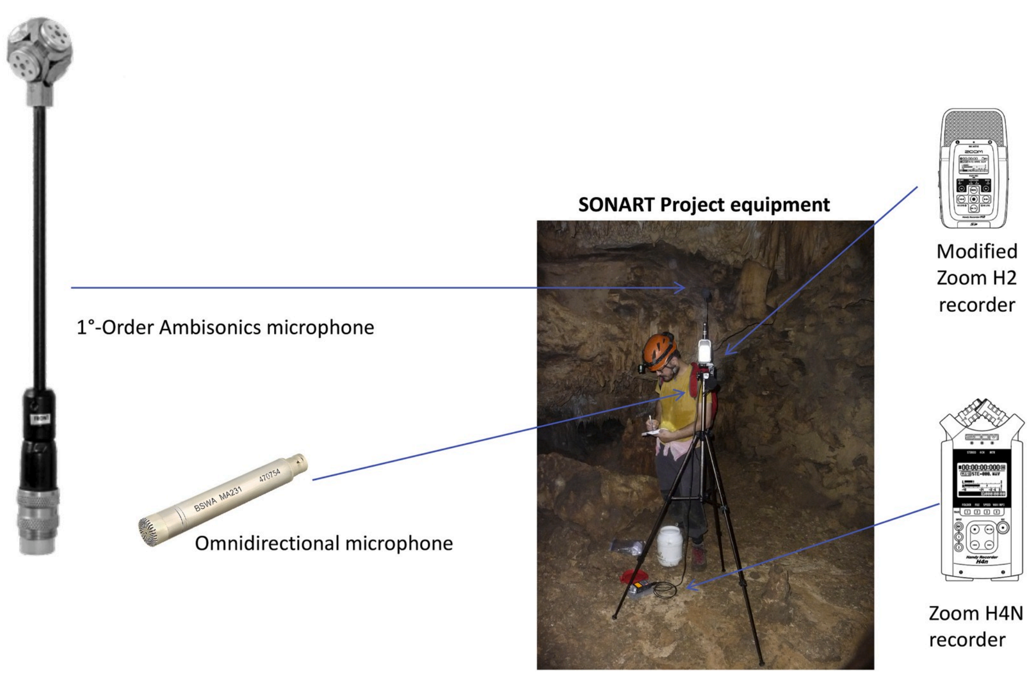

Fig. 5. The two types of microphone used and the digital recorders used to take measurements in the SONART and the Palarq projects. Own elaboration. Photo made in Belize: Margarita Díaz-Andreu.

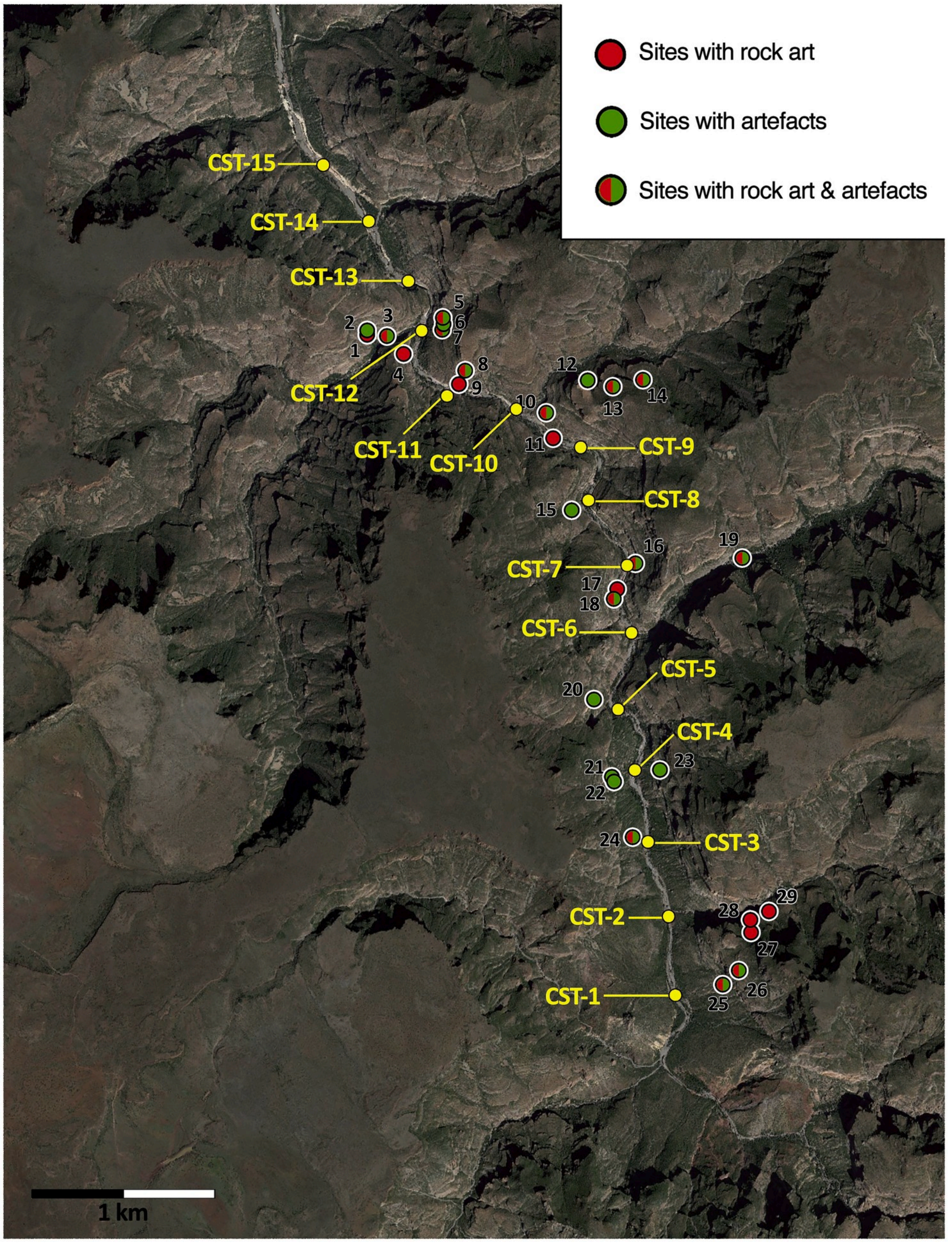

Fig. 6. Map marking archaeological sites and the location of the fifteen test points of the acoustic test along the canyon bed of the Arroyo de San Pablo/Cañón de Santa Teresa. 1. Al O del Sitio no 11; 2. San Julio; 3. C. de San Julio or C. Boca de San Julio; 4. C. de La Liebre; 5. C. de La Venada; 6. C. al Norte de Los Músicos; 7. C. de Los Músicos or Cueva de la Música or Cueva de la Boca de San Julio II; 8. C. del Los Corralitos or La Cuevona; 9. Zopilote y Pez; 10. La Piedra del Chuy; 11. C. de la Piedra Blanca Grabada (with modern engravings); 12. C. de Los Murciélagos; 13. C. del Morro del Cacarizo or Cacarizo II or C. de los Monos Blancos; 14. C. del Cerro Cacarizo or Cacarizo I or C. de la Cañada del Cacarizo; 15. C. del Cantil Caido; 16. C. Pintada; 17. Las Flechas 2; 18. Las Flechas; 19. C. de La Soledad or C. del Pajaro Negro or C. de las Aguilas; 20. C. del Granadillo; 21. C. de La Falda de La Mesa del Corral 2; 22. C. de La Falda de La Mesa del Corral 1; 23. C. de la Piedra Rodada; 24. C. de la Rata; 25. C. del Mezquite or El Borrego 2; 26. C. del Banco de Santa Teresa or El Borrego 1; 27. C. de Santa Teresa 1; 28. C. de Santa Teresa 2; 29. C. de Santa Teresa 3.

music, dance and singing led us to add a series of monaural and binaural acoustic parameters to be measured. Regarding monaural acoustic parameters, we tested for strength, reverberation, speech clarity and clarity index for music. Strength (G) is used to measure perceived loudness of sound (Barron, 2010; Kuttruf, 2009). Optimum values are located between +1 dB and +10 dB (Kuttruf, 2009, p. 153). The just noticeable difference (JND) for G is 1 dB according to the ISO (ISO 3382-1 2009). Reverberation (T20) represents the impression of sound persistence after sound is produced (Kuttruf, 2009, pp. 229–237, Barron, 2010, pp. 461–463). Speech clarity (C50) is particularly suited to assessing the quality of speech signals (Kuttruf, 2009, pp. 221–229, Barron, 2010, pp. 461–463). Optimum C50 values for good speech intelligibility are between −2 dB and +2 dB. The just noticeable difference (JND) for C50 is ± 4 dB for 90% of listeners according to Bradley (Bradley et al. 1999). Finally, music clarity (C80) is widely accepted as a useful criterion for the clarity and transparency of musical sounds and its typical range is from −5 to + 3 dB (Kuttruf, 2009, p. 225).

Envelopment and Apparent Source Width were tested as binaural acoustic parameters. Envelopment (LJ) refers to the listener's impression of being inside and surrounded by the reverberant sound field (Kuttruf, 2009, pp. 239–242). The higher the Lj value, the stronger the envelopment. Apparent source width (Jlf) is related to the perceived broadness of the sound source (Kuttruf, 2009, pp. 239–242). The lower the value, the better the accuracy in perceiving the true physical extent of the sound source.

3.2. *Testing the acoustics of the canyon*

The first objective of our study was to investigate the relationship between the acoustics of the landscape and the placement of rock art sites in the Cañón de Santa Teresa. For this purpose, a segment of the canyon was selected. This segment included sites with a large number of figures–i.e. Cueva Pintada, Las Flechas and Boca San Julio – and also others with fewer figures, in addition to a series of shelters with only artifacts, but no rock art, and others with no evidence of human presence. Altogether, fifteen test points were selected on the canyon bed at a regular distance of 500 m apart dividing up the selected segment of the valley into 13 sectors (see Fig. 6). Most sectors had one or several rock

Table 2
Results of the acoustics analyses along the canyon by sector, rows being organized by the number of rock art sites in each sector. The columns include the number of rock art sites within a 250-m radius of the test point; sector identification number (ID); type of site (A = artifacts; C = rock art carvings; P = rock art paintings); name(s) of the archaeological sites associated with each test point; acoustic parameters analyzed. The underlined results indicate good values. Double underlining indicates the best values.

# of rock art sites within 250 m	Test ID	Type of site	Site(s) Name(s)	Monaural acoustic parameters				Binaural ac. parameters		# of good parameters
				G	T20	C50	C80	Lj	Jlf	
4	CST-12	P + A	C. de San Julio o Boca de S. Julio	**18.7**	0.5	**13.5**	**13.8**	**−9.0**	0.13	**4**
		P	C. de la Liebre							
		P + A	C. de Los Músicos/de la Música							
		A	C. al Norte de Los Músicos							
		P + A	C. de la Venada							
3	CTS-7	P + A P + A	C. Pintada	15.6	**0.7**	**12.1**	**16.5**	**−10**	**0.27**	**5**
		P	Las Flechas							
			Las Flechas 2							
2	CST-11	C + A	C. de los Corralitos/La Cuevona	**16.9**	0.5	**15.3**	**16.9**	**−5.0**	**0.18**	**5**
		P	Zopilote y pez							
1	CTS-3	P + A	C. de La Rata	15.0	0.4	16.5	19.4	−13.3	0.1	0
1	CST-10	C + A	Piedra de Chuy	**16.8**	**0.8**	**11.8**	**15.3**	**−9.5**	**0.22**	**6**
0	CTS-1			**16.3**	0.4	20.3	23.0	−17.6	0.07	1
0	CTS-2			14.1	0.3	20.1	23.8	−19.1	0.07	0
0	CTS-4	A	C. de la Falda Mesa del Corral 1	12.1	0.5	17.3	18.8	**−6.2**	0.09	1
		A	C. de la Falda Mesa del Corral 2							
		A	C. de la Piedra Rodada							
0	CTS-5	A	C. del Granadillo	**17.0**	0.5	**13.2**	19.2	**−8.5**	0.1	3
0	CTS-6			**18.0**	0.5	16.8	**17.1**	−15.2	**0.19**	3
0	CTS-8	A	C. del Cantil Caído	15.1	**0.6**	16.3	**16.8**	**−6.2**	0.11	**4**
0	CST-9	C	C. de la Piedra Blanca Grabada	14.9	**0.6**	**13.9**	**14.6**	**−10.7**	0.09	**4**
0	CST-14			13.7	**1.0**	19.3	19.1	−13.5	0.13	1
0	CST-15			**16.1**	0.3	19.7	20.5	−12.1	0.06	0

art sites except sector CST-4 which only had three sites with artifacts in it.

The analysis of the acoustics along the canyon was carried out by using 14 audio recordings taken with the Zoom H4N Digital Recorder connected to the omnidirectional microphone and another 14 with the Digital Recorder ZOOM H2 connected to the first-order Ambisonics Brahma™ microphone. The results are given in Table 2. The recordings made at Point 13 (CST-13) had to be dismissed as the sound recorded in the audio files was drowned out by the high wind. For each test point we computed the monaural and binaural acoustic parameters listed in Section 3.1 and compared the results with the number and type of associated archaeological site by selecting those that were within a buffer area extending 250 m around each test point. We will refer to each buffer area as a canyon sector. The results are given in Table 2 and Fig. 7.

As seen in Table 2, although rock art artists were interested in the acoustics of the place, no particular acoustic parameter was considered to be essential for the location of rock art. However, as the last column of the table shows, taken altogether the results of the acoustic analyses clearly show a positive relationship between good values and the number of rock art sites in a sector of the canyon. This seems to indicate that, generally speaking, those sectors with good sonic environments were especially liked for the production of rock art. However, the results of CST-10 are particularly striking. As a sector with a single site, the high values appear exceptional. The rock art site is the Piedra de Chuy, where there are no paintings, only carvings (Fig. 3).

The analysis of the results by sector, discriminating the best values (indicated in Table 2 with a double underline) from those that are good (underlined with one line) or just fair (plain text), allows us to refine the appreciations above. Best values of Strength, Reverberation, Listener Envelopment and Apparent Source Width are those that exceed the main value recorded in the canyon, while the best values of Speech and Music Clarity are those closer to the ISO 3382–1:2009 standard ranges. Best values were ranked by us with one point. Good values are defined here as acoustic values that are between the main value recorded in the whole canyon and/r the best value. Good values were ranked by us with 2 points. A rank of 3 points corresponds to the rest of values. The results of our ranking are illustrated in Table 3 and from them several conclusions can be drawn. First, Sector CST-7, i.e. the sector of the canyon with the exceptional sites of Cueva Pintada and Las Flechas, provides the best score. This means that rock art artists produced the most exceptional paintings in the best sonic environment in the canyon. Secondly, all the sites with ancient carvings (Piedra de Chuy and Cueva de Los Corralitos) are among the first three positions in our acoustic rankings. This means that the rock art artists purposely chose some of the most prominent sonic environments in the whole area to produce their carvings. Lastly, all the sectors without rock art are on the bottom of the table. This means that the shelters and caves close to river sectors with the poorest acoustic qualities were not chosen to be decorated. In conclusion, our findings support the hypothesis of a positive correlation between good acoustics along the canyon and the presence of rock art in the nearby shelters and caves.

3.3. *Testing the acoustics of rock art sites*

Monaural and binaural acoustic parameters were also acquired in two of the major rock art sites of the valley, the Cueva Pintada and Las Flechas rock art sites, and in seven non-decorated shelters in the same area. This experiment was specifically designed to compare the acoustics of the interior spaces of shelters at major rock art sites with those without rock art. Given the fact that sound and music are always present in ritual and ceremonies, as anthropologists have repeatedly pointed out (Bloch, 1989, p. 21, Nettl, 2000), and the ethnohistorical sources on Baja California Sur seem to imply (although never in relation to the shelters themselves), we were particularly interested in ascertain whether rock art artists sought out places where sound events could be enhanced and reinforced. Our hypothesis was that there would indeed be a positive relationship between rock art sites and good acoustics.

Cueva Pintada and Las Flechas are two exceptional rock art sites in the Cañón de Santa Teresa. The former encompasses a series of shelters with a total length of 212 m, 182 m of which are painted. This is clearly a key site with an impressive 1494 figures recently meticulously described and analyzed by Viñas (2013). The rock art of the latter site, Las Flechas, is well known for its exceptional preservation and the imposing figures

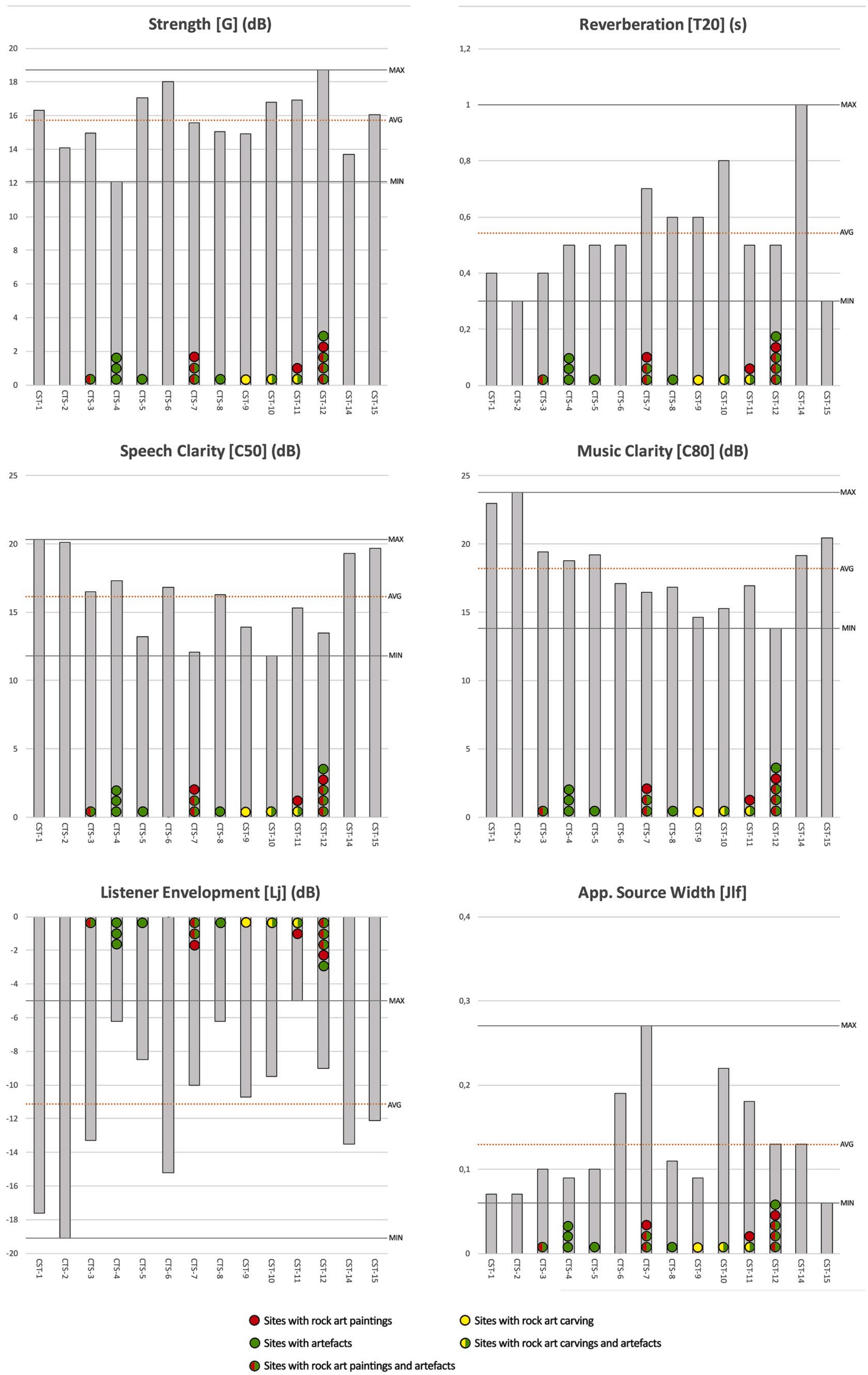

Fig. 7. Graphic results of the analysis of the acoustics along the canyon according to acoustic cues.

Table 3
–Ranked list of canyon sectors according to their overall acoustic qualities from best to worse. The number and type of archaeological sites associated with each test point are indicated (P = paintings; C = carvings; A = artifacts; TOT = total number of sites.

Sector	# of rock art sites within 250m	Acoustic ranking	Sites	P	C	A	P + A	C + A	TOT
CST-7	3	11	C. Pintada Las Flechas Las Flechas 2	1			2		3
CST-10	1	11	Piedra del Chuy					1	1
CST-11	2	12	C. de los Corralitos Zopilote y pez	1				1	2
CST-12	4	12	C. de San Julio C. de la Liebre C. de Los Músicos C. al Norte de Los Músicos C. de la Venada	1		1	3		5
CST-6	0	14							
CST-9	0	14	C. de la Piedra Blanca Grabada		1				1
CST-5	0	15	C. del Granadillo			1			1
CST-8	0	15	C. del Cantil Caido			1			1
CST-14	0	16							
CST-1	0	17							
CST-4	0	17	C. de la Falda de la Mesa del Corral 1 C de la Falda de la Mesa del Corral 2 C. de la Piedra Rodada			3			3
CST-15	0	17							
CST-2	0	18							
CST-3	1	18	C. de La Rata				1		1

Table 4
Acoustic parameters of the C. Pintada and Las Flechas rock art sites compared to a sample of seven shelters without rock art in the Cañón de Santa Teresa.

	G	T20	C50	C80	Lj	Jlf
Cueva Pintada	16.5	0.3	12.8	18.3	−9.8	0.3
Las Flechas	17.3	0.3	11.6	19.8	−5.0	0.6
AVG	**16.9**	**0.3**	**12.2**	**19.1**	**−7.4**	**0.5**
	G	**T20**	**C50**	**C80**	**Lj**	**Jlf**
C. al Norte de Los Músicos	20.2	0.2	16.1	19.8	−10.9	0.6
C. de los Murciélagos	15.3	0.5	9.8	14.9	−3.3	0.2
C. del Cantil Caído	18.8	0.6	7.0	11.2	0.4	0.2
C. del Granadillo	19.4	0.3	13.9	20.5	−15.7	0.2
C. de la F. Mesa del Corral 1	17.8	0.3	9.3	16.3	−7.6	0.1
C. de la F. Mesa del Corral 2	19.1	0.4	12.9	17.9	−7.2	0.2
C. de la Piedra Rodada	20.0	0.3	16.5	20.4	−10.9	0.2
AVG	**18.7**	**0.4**	**12.2**	**17.3**	**−7.9**	**0.3**

crossed by arrows and with distinctive headdresses. In comparison to Cueva Pintada, Las Flechas is a much smaller shelter (approximately 15 m long and 9 m deep) and correspondingly it has fewer figures. These sites are almost opposite each other in CST-7, Las Flechas first facing east, and going downstream about 250 m beyond the site of Cueva Pintada facing west. On the river bed in the area between the sites there is a water spring that would have been a key resource used by the communities living in the area.

Contrary to our hypothesis, the results of Table 4 show that, acoustically speaking, there is no apparent distinction between the shelters where rock art was produced and those that were left undecorated. These results demonstrate that in Cañón de Santa Teresa the connection between the placement of rock art in particular rock shelters and place with specific acoustic qualities is not supported.

4. Conclusions

In this article it has been suggested that the study of intangible aspects of culture such as sound should also be part of the new focus on quantitative methods in archaeology. The changes that archaeology has been going through in the last couple of decades, in what Kristian Kristiansen (2014) has called the Third Science Revolution in archaeology, can also be seen in the increasing application of rigorous science-based methodologies for the study of the acoustics of archaeological objects and landscapes. From an initial phase defined by an unsystematic approach to another in which the focus was on testing the presence of echoes, reverberation and resonance, in this article we have shown that a more sophisticated exploration of acoustic parameters is possible. Borrowing from methodologies developed in acoustical physics we have included additional parameters in our exploration. Among the monoaural aspects, in addition to reverberation (T20), we have tested strength (G), speech clarity (C50) and music clarity (C80). Binaural acoustic cues studied include listener envelopment (Lj) and apparent source width (Jlf). Our intention has been to determine whether or not ancient communities were interested in places with high values of one of these parameters or a combination of them. Our findings have given us clues to their degree of complex understanding of sonic landscapes.

In the case study analyzed, the Cañón de Santa Teresa gorge in Baja California Sur (Mexico), we have been able to demonstrate that the communities who produced the Great Mural rock art tradition did indeed select the best sonic environments for the creation of rock art, both for paintings and, especially, carvings. Despite this, no particular acoustic cue was perceived as essential by these communities. The acoustic analysis summarized in Table 3 has indicated that it is precisely in the canyon sector with the most favorable acoustic conditions that we find the concentration of two profusely painted caves: those of Cueva Pintada and Las Flechas. However, contrary to our initial expectations, the study of the interior acoustics of those shelters did not provide particularly significant results, as they were similar to those of the undecorated shelters nearby. Looking at the distribution of the archaeological remains in all types of shelters perhaps we should have never expected positive results: in these shelters it is not infrequent to find querns (*metates*) both on the surface area and in stratigraphy in the few excavations undertaken at some sites (see Section 2.1 above), indicating their unsuitability as areas for dancing in ceremonies, an activity referred to by the ethnohistorical sources written at the time of the European settlement in the area in the eighteenth century (see Section 2.2 above). As explained in the article, it is important to understand the relative validity of the sources. As the chronology of the paintings indicates that they were produced much earlier than the arrival of Europeans, the information given in the sources can only be relevant if the roots of the traditions they refer to go back far enough to coincide with the period in which the paintings were made. However, given that dancing was so widespread in the various ethnic groups that inhabited the Baja California peninsula in the eighteenth century, and indeed that this activity is very common among hunter-gatherer communities, we believe it is not unreasonable to assume that dancing was also important among the communities that produced the art. We would like to hypothesize that relatively wide, flat areas such as the one found at the bottom of the gorge in the sector where Cueva Pintada and Las Flechas are located (Fig. 4) was potentially ideal for this activity. The presence of a spring would also have increased the suitability of this space as a collective area for community gathering and dancing. Proving or disproving this proposal is no longer feasible. Even if our assumption is correct, any archaeological evidence of such gatherings on the relatively flat area at the bottom of the gorge has long ago been washed away, given the very infrequent, but relatively regular, floods in the area.

The study of the acoustic features of rock art landscapes and sites undertaken in this article has provided us with new clues for our understanding of what the rock art artists who produced the Great Mural tradition of Baja California Sur were looking for when seeking out places in which to paint. Through their paintings and carvings they were able to illustrate their own mythical stories in places associated with a wider area in which community and ritual activities took place. The application of quantitative methods borrowed from physical acoustics has allowed us to suggest that, in addition to other features, the ancient communities that created the rock art panels did indeed generally consider the sonic qualities of landscape as relevant to the production and experience of rock art.

The Third Science Revolution (cf. Kristiansen, 2014) is bringing sound back to the realm of archaeological enquiry. Rigorous, scientific-based methods allow making links between the tangible and the intangible, opening new opportunities to approach aspects of culture that seemed to be lost to archaeology. This article has illustrated this in relation to the rock art landscapes of Baja California but we suspect that much more can be learned from the collaboration with other sciences. Archaeology is changing and rock art needs to be part of this transformation towards a more interdisciplinary and even transdisciplinary way of approaching the past.

Declaration of competing interest

The authors of the submitted article “The soundscapes of Baja California Sur: preliminary results from the Cañón de Santa Teresa rock art landscape” declare no conflict of interest.

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References

Aschmann, H., 1959. The Central Desert of Baja California: Demography and Ecology. Ibero-Americana, vol. 42. University of California Press, Berkeley.
Baegert, J.J., 1952. Observations in Lower California. Translated from German by M.M. Brandenburg and C. L. Baumann, 1772. University of California Press, Berkeley.
Barco, M. del, 1973. Historia Natural y Crónica de la Antigua California, Edición a cargo de Miguel León Portilla, 1773-1780. UNAM, México.
Barron, M., 2010. Auditorium Acoustics and Architectural Design, second ed. edition. Spon Press, London.
Bloch, M., 1989. Ritual, History and Power: Selected Papers in Anthropology, vol. 58. London School of Economics Monographs on Social Anthropology, AthIone, London.
Bradley, J.S., Reich, R., Norcross, S.G., 1999. A just noticeable difference in C50 for speech. Appl. Acoust. 58, 99–108.
Bronk Ramsey, C., 2001. Development of the radiocarbon calibration program. Radiocarbon 43 (2), 355–363.
Bronk Ramsey, C., 2009. Bayesian Analysis of radiocarbon dates. Radiocarbon 51 (1), 337–360.
Clavijero, F.J., 1982. Historia de la Antigua o Baja California, 1789, 3[a] edición edition. Porrúa, México.
Corbin, A., 1998. Village Bells. The Culture of the Senses in the Nineteenth-Century French Countryside. Columbia University Press, New York.
Crosby, H., 1975. The Cave Paintings of Baja California, the Great Murals of an Unknown People. Copley Press, Salt Lake City, Utah.
Crosby, H.W., 1997. Cave Paintings of Baja California: Discovering the Great Murals of an Unknown People, revised edition. Sunbelt Publications, San Diego.
Díaz-Andreu, M., García Atiénzar, G., García Benito, C., Mattioli, T., 2017. Do you hear what I see? Analyzing visibility and audibility through alternative methods in the rock art landscape of the Alicante mountains. J. Anthropol. Res. 73, 181–213.
Díaz-Andreu, M., García Benito, C., 2012. Acoustics and levantine rock art: auditory perceptions in La valltorta gorge (Spain). J. Archaeol. Sci. 39, 3591–3599.
Diguet, L., 1895. La pictographie de la Basse-Californie. L'Anthropologie 6, 160–175.
Farina, A., Capra, A., Conti, L., Martignon, P., Fazi, F., 2007. Measuring spatial impulse responses in concert halls and opera houses employing a spherical microphone array. In: 19th International Congress on Acoustics Madrid.
Fazenda, B., Scarre, C., Till, R., Jiménez Pasalodos, R., Rojo Guerra, M., Tejedor, C., Ontañon Peredo, R., Watson, A., Wyatt, S., García Benito, C., Drinkall, H., Foulds, F., 2017. Cave acoustics in prehistory: exploring the association of Palaeolithic visual motifs and acoustic response. J. Acoust. Soc. Am. 142, 1332–1349.
Feld, S., Brenneis, D., 2004. Doing anthropology in sound. Am. Ethnol. 31 (4), 461–474.
Fullola, J.M., Petit, M.A., Rubio, A., Castillo, V. del, Bergadà, M.M., 1993. Esquema crono-cultural del poblamiento prehistórico de las sierras centrales de la península de Baja California, México. Arqueologia [Subd. de Arqueología del INAH] 9-10, pp. 3–15.
Goldhahn, J., 2002. Roaring rocks: an audio-visual perspective on hunter-gatherer engravings in northern Sweden and scandinavia. Norweg. Archaeol. Rev. 35 (1), 29–61.
Gutiérrez Martínez, M. de la L., 2013. Paisajes ancestrales. Identidad, memoria y arte rupestre en las cordilleras centrales de la península de Baja California. Tesis que para optar por el grado de Doctora en Arqueología, Director de Tesis. Dr. Stanislaw Iwaniszewski. Escuela Nacional de Antropología e Historia, México.
Gutiérrez Martínez, M. de la L., 2017. Cueva Pintada, Sierra de San Francisco, en el contexto de los grandes murales de la parte central de la península de Baja California, México. XXII Coloquio de Historia Canario-Americana. Las Palmas de Gran Canaria, p. 123.
Gutiérrez Martínez, M. de la L., Hernández, M.I., Watchman, A., 2003. Antigüedad de los murales rupestres de la península de Baja California. Arqueol. Mex. 60, 4–5.
Gutiérrez Martínez, M. de la L., Hyland, J.R., 2002. Arqueología de la Sierra de San Francisco. Dos décadas de investigación del fenómeno Gran Mural. Col. Científica, serie histórica. INAH, México.
Hambleton, E., 1979. La pintura rupestre de Baja California. Fondo de Cultura Banamex, México.
Ingold, T., 2000. The Perception of the Environment: Essays on Livelihood, Dwelling and Skill. Routledge, London.
ISO 3382-1, 2009. Acoustics - Measurement of Room Acoustic Parameters - Part 1: Performance Spaces. International Organization for Standardization, Geneva.
Kristiansen, K., 2014. Towards a new paradigm? The Third science revolution and its possible consequences in archaeology. Curr. Swed. Archaeol. 22, 11–71.
Kuttruf, H., 2009. Room Acoustics, fifth ed. Taylor & Francis, New York.
Laylander, D., 2005. Ancestors, ghosts, and enemies in prehistoric Baja California. J. Calif. Great Basin Anthropol. 25, 169–186.
Laylander, D., 2015. William C. Massey's contributions to Baja California prehistory. Pac. Coast Archaeol. Soc. Q. 51, 2.
Laylander, D., 2018. Eric ritter's role in the development of prehistoric archaeology in Baja California. Pac. Coast Archaeol. Soc. Q. 53, 1–35.

Massey, W.C., 1949. Tribes and languages of Baja California. SW. J. Anthropol. 5, 272–307.
Massey, W.C., 1966. Archaeology and ethnohistory of lower California. In: Ekholm, G.F., Gordon, W., Wauchope, R. (Eds.), Archaeological Frontiers and External Connections. University of Texas Press (Handbook of Middle American Indians IV), Austin, pp. 38–58.
Massey, W.C., Osborne, C.M., 1961. A Burial Cave in Lower California: the Palmer Collection, 1887, vol. 16. University California Anthropological Records.
Mathes, W.M., 2006. Ethnohistoric evidence. In: Laylander, D., Moore, J.D. (Eds.), The Prehistory of Baja California: Advances in the Archaeology of the Forgotten Peninsula. University of Florida Press, Gainesville, pp. 42–66.
Mattioli, T., Díaz-Andreu, M., 2017. Hearing rock art landscapes. A survey of the acoustical perception in the Sierra de San Serván area in Extremadura (Spain). Time Mind 10, 81–96.
Mattioli, T., Farina, A., Armelloni, E., Hameau, P., Díaz-Andreu, M., 2017. Echoing landscapes: echolocation and the placement of rock art in the Central Mediterranean. J. Archaeol. Sci. 83, 12–25.
Meighan, C.W., 1966. Prehistoric rock paintings in Baja California. Am. Antiq. 31, 372–392.
Millard, A., 2014. Conventions for reporting radiocarbon determinations. Radiocarbon 56 (2), 555–559.
Mixco, M.J., 2006. The indigenous languages. In: Laylander, D., Moore, J.D. (Eds.), The Prehistory of Baja California: Advances in the Archaeology of the Forgotten Peninsula. University of Florida Press, Gainesville, pp. 24–41.
Mlekuz, D., 2004. Listening to the landscapes: modelling soundscapes in GIS. Internet Archaeol. 16 online).
Morley, I., 2006. Hunter-gatherer music and its implications for Identifying Intentionality in the use of acoustic space. In: Scarre, C., Lawson, G. (Eds.), Archaeoacoustics. McDonald Institute for Archaeological Research, University of Cambridge (McDonald Institute Monographs), Cambridge, pp. 95–105.
Nettl, B., 2000. An ethnomusicologist contemplates musical universals. In: Wallin, N.L., Merker, B., Brown, S. (Eds.), The Origins of Music. MIT Press, Cambridge, MA, pp. 463–472.
Ortega Noriega, S., 2010. Crecimiento y crisis del sistema misional: 1686-1767. In: Ortega Noriega, S., Río, I. del (Eds.), Tres siglos de historia sonorense, 1530-1830. Universidad Nacional Autónoma de México, Instituto de Investigaciones Históricas, México, pp. 135–184.
Pätynen, J., Katz, B.F.G., Lokki, T., 2011. Investigations on the balloon as an impulse source. J. Acoust. Soc. Am. 129.
Rainio, R., Lahelma, A., Äikäs, T., Lassfolk, K., Okkonen, J., 2014. Acoustic measurements at the rock painting of várikallio, northern Finland. In: Eneix, L.C. (Ed.), Archaeoacoustics: the Archaeology of Sound. Publication of Proceedings from the, 2014 Conference in Malta. The OTS Foundation, Myakka, pp. 141–152.
Rainio, R., Lahelma, A., Äikäs, T., Lassfolk, K., Okkonen, J., 2017. Acoustic measurements and digital image processing suggest a link between sound rituals and sacred sites in northern Finland. J. Archaeol. Method Theory 25 (2), 453–474.
Reznikoff, I., 1987. Sur la dimension sonore des grottes à peintures du Paléolitique, 304 C. R. Acad. Sci. 305, 307–310, 53-156.
Reznikoff, I., 1995. On the sound dimension of prehistoric painted caves and rocks. In: Taratsi, E. (Ed.), Musical Signification. Mouton de Gruyter, Berlin, pp. 541–557.
Reznikoff, I., 2018. On foundations of archaeoacoustics. In: Eneix, L.C., Ragussa, M.W. (Eds.), Archaeoacoustics III - the Archaeology of Sound: Publication of Proceedings from the, 2017 Conference in Portugal. OTS Foundation, Myakka, pp. 155–166.
Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., et al., 2013. IntCal13 and Marine 13 radiocarbon age calibration curves 0-50,000 years cal BP. Radiocarbon 55 (4), 1869–1887.
Ritter, E.W., 1991. Baja California rock art: problems, progress, and prospects. In: Hedges, K. (Ed.), San Diego Museum Papers, vol. 17. San Diego Museum, San Diego, pp. 21–56.
Ritter, E.W., 2006. South-central Baja California. In: Laylander, D., Moore, J.D. (Eds.), The Prehistory of Baja California: Advances in the Archaeology of the Forgotten Peninsula. University of Florida Press, Gainesville, pp. 99–116.
Ritter, E.W., Aceves Calderón, P., 2006. Fragments of Archaeological Landscapes in North-Central Baja California, Mexico. Memorias: balances y perspectivas de la antropología e historia de Baja California 7. Centro INAH Baja California, La Paz, pp. 61–96.
Rubio, A., 1991. Los jesuitas en Baja California. Cuad. Hispanoam. 497, 48–69.
Rubio, A., 2014. El yacimiento arqueológico de El Ratón. Una cueva con pinturas en la Sierra de San Francisco (Baja California Sur, México). El mural pintado. Monografies del SERP 10. Universitat de Barcelona, Barcelona.
Sales, L., 1794. Noticias de la Provincia de Californias en tres cartas de un sacerdote religioso hijo del Real Convento de Predicadores de Valencia a un amigo suyo. Hermanos de Orga, Valencia.
Scarre, C., Lawson, G. (Eds.), 2006. Archaeoacoustics. McDonald Institute for Archaeological Research, Cambridge.
Stuiver, M.A., Polach, H.A., 1977. Reporting of 14C data. Radiocarbon 19 (3), 355–363.
Stuiver, M.A., Reimer, P.J., 1993. Extended 14C data base and revised CALIB 3.0 `4C age calibration program. Radiocarbon 35 (1), 215–230.
Till, R., 2014. Sound archaeology: terminology, Palaeolithic cave art and the soundscape. Special issue. In: Schofield, J. (Ed.), World Archaeology, vol. 46, pp. 292–304. Music & Sound.
Viñas, R., 2013. La Cueva Pintada. Proceso evolutivo de un centro ceremonial, Sierra de San Francisco, Baja California Sur, México. Monografies del SERP 9. Universitat de Barcelona, Barcelona.
Waller, S.J., 2000. Spatial correlation of acoustics and rock art in Horseshoe canyon. Am. Indian Rock Art 24, 85–94.
Waller, S.J., 2002. Rock art acoustics in the past, present and future. American Indian rock art. special issue. In: Whitehead, P., Whitehead, W., Loendorf, L. (Eds.), 1999 IRAC Proceedings, vol. 2, pp. 11–20, 26.
Waller, S.J., 2006. Intentionality of rock-art placement deduced from acoustical measurements and echo myths. In: Scarre, C., Lawson, G. (Eds.), Archaeoacoustics. McDonald Institute for Archaeological Research, University of Cambridge (McDonald Institute Monographs), Cambridge, pp. 31–40.
Watchman, A., Gutiérrez Martínez, M. de la L., Hernández Llosas, M.I., 2002. Giant murals of Baja California: new regional archaeological perspectives. Antiquity 76, 947–948.
Wilken-Robertson, M., Laylander, D., 2006. Ethnography. In: Laylander, D., Moore, J.D. (Eds.), The Prehistory of Baja California: Advances in the Archaeology of the Forgotten Peninsula. University of Florida Press, Gainesville, pp. 67–81.